EOS TECHNOLOGIES, INC.

LICK

2.4m Telescope

One-piece Truss Design

Finite Element Analysis

FEA-12624-1

EOS Technologies, Inc. • 3160 East Transcon Way, Suite 180 • Tucson AZ 85706 • USA
Tel: +1 520 624 6399 • Fax: +1 520 624 1906 • Web: www.eostech.com

DOCUMENT CONTROL

Issue: 1

Prepared:	Kerry Gonzales	K. Gonzales	Date: 8/15/2007
Checked:	D. Shelby Stubbe	D. Shelby Stubbe	Date: 8/15/2007
Approved:	Kevin Harris	Kevin R Harris	Date: 8/15/2007
Configured:	Edith Hatch	Edith Hatch	Date: 8/15/2007

Document Revisions

Issue	Date	Description	Prep	Chk	Appr
1	8/15/2007	Initial Release			

TABLE OF CONTENTS

LICK

One-piece Truss Design Analysis

1 INTRODUCTION

1.1 SCOPE

This document describes the finite element analysis of the One-piece Truss design, COM-5280.

1.2 CONFIGURATION

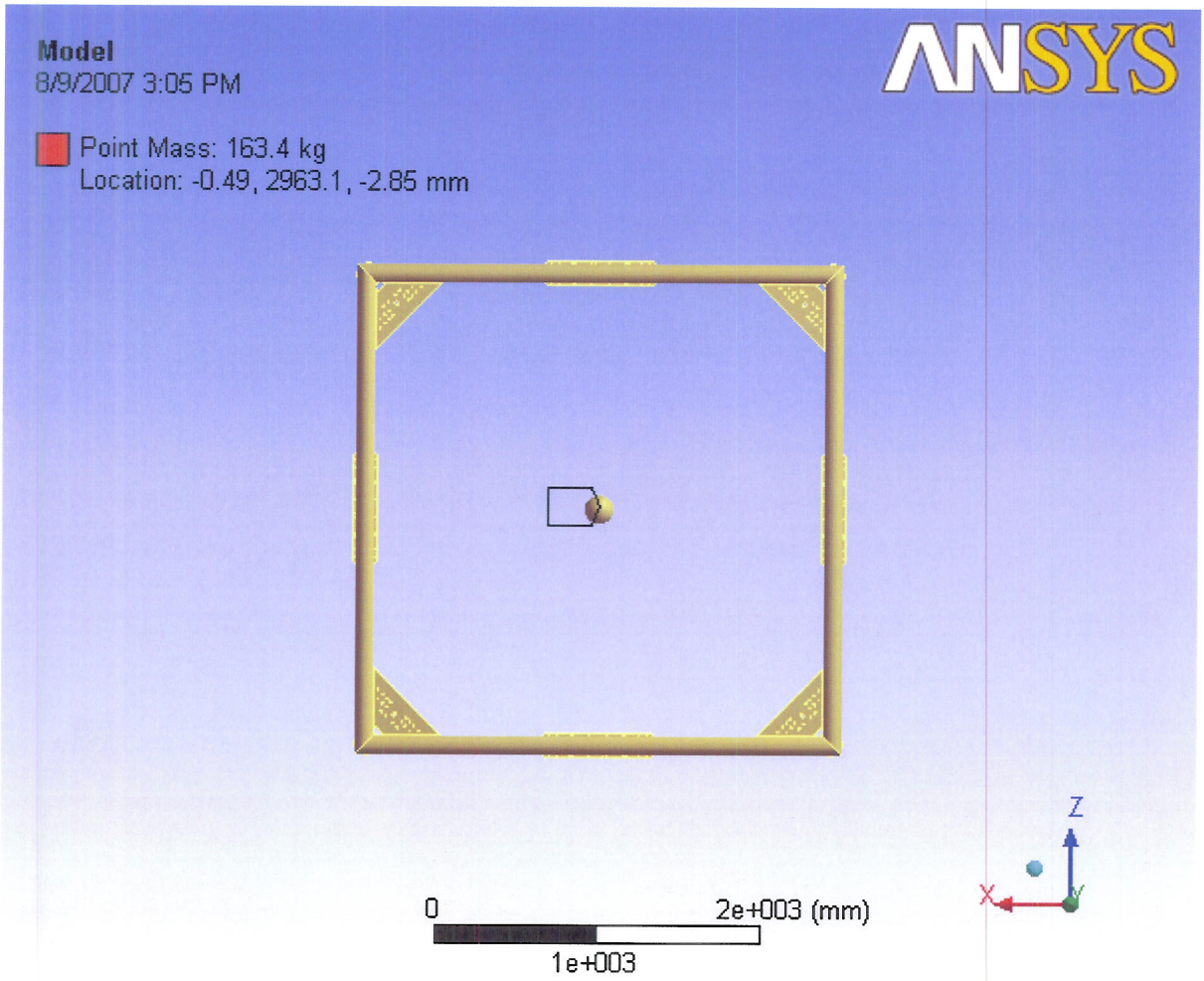
This manual has been configured as FEA-12624-1 and is a designated controlled document under the EOS Quality System.

1.3 ANALYSIS DOCUMENT

The following document, consisting of 25 pages, outlines the analysis and results for the One-piece Truss design. This document constitiutes the body of this report.

Project

First Saved	Thursday, August 09, 2007
Last Saved	Thursday, August 09, 2007
Product Version	11.0 Release



Contents

Units

TABLE 1

Unit System	Metric (mm, kg, N, °C, s, mV, mA)
Angle	Degrees
Rotational Velocity	rad/s

Model

Geometry

TABLE 2
Model > Geometry

Object Name	*Geometry*
State	Fully Defined
Definition	
Source	P:\Lick Telescope\mechanical\drawings\COM-5280.SLDASM
Type	SolidWorks
Length Unit	Meters
Element Control	Program Controlled
Display Style	Part Color
Bounding Box	
Length X	3020. mm
Length Y	2665.5 mm
Length Z	3020. mm
Properties	
Volume	1.6363e+008 mm³
Mass	1447.9 kg
Statistics	
Bodies	1
Active Bodies	1
Nodes	178033
Elements	90908
Preferences	
Import Solid Bodies	Yes
Import Surface Bodies	Yes
Import Line Bodies	Yes
Parameter Processing	Yes
Personal Parameter Key	DS
CAD Attribute Transfer	No
Named Selection Processing	No
Material Properties Transfer	No
CAD Associativity	Yes
Import Coordinate Systems	No
Reader Save Part File	No
Import Using Instances	Yes
Do Smart Update	No
Attach File Via Temp File	No
Analysis Type	3-D
Mixed Import Resolution	None
Enclosure and Symmetry Processing	Yes

TABLE 3
Model > Geometry > Body Groups

Object Name	*COM-5281-1*
State	Meshed
Graphics Properties	
Visible	Yes

Definition	
Suppressed	No
Material	Structural Steel
Bounding Box	
Length X	3020. mm
Length Y	2665.5 mm
Length Z	3020. mm
Properties	
Volume	1.6363e+008 mm³
Mass	1284.5 kg
Statistics	
Nodes	178033
Elements	90908

TABLE 4
Model > Geometry > COM-5281-1 > Parts

Object Name	*Part*
State	Meshed
Graphics Properties	
Visible	Yes
Transparency	1
Definition	
Suppressed	No
Material	Structural Steel
Stiffness Behavior	Flexible
Nonlinear Material Effects	Yes
Bounding Box	
Length X	3020. mm
Length Y	2665.5 mm
Length Z	3020. mm
Properties	
Volume	1.6363e+008 mm³
Mass	1284.5 kg
Centroid X	-0.58003 mm
Centroid Y	2343.7 mm
Centroid Z	-0.49127 mm
Moment of Inertia Ip1	2.6465e+009 kg·mm²
Moment of Inertia Ip2	3.3586e+009 kg·mm²
Moment of Inertia Ip3	2.6458e+009 kg·mm²
Statistics	
Nodes	178033
Elements	90908

TABLE 5
Model > Geometry > Point Masses

Object Name	*Point Mass*
State	Fully Defined
Scope	
Geometry	4 Faces

X Coordinate	-0.49 mm
Y Coordinate	2963.1 mm
Z Coordinate	-2.85 mm
Location	Defined
Definition	
Mass	163.4 kg
Mass Moment of Inertia X	0. kg·mm²
Mass Moment of Inertia Y	0. kg·mm²
Mass Moment of Inertia Z	0. kg·mm²
Suppressed	No
Behavior	Deformable

Connections

TABLE 6
Model > Connections

Object Name	*Connections*
State	Fully Defined
Auto Detection	
Generate Contact On Update	Yes
Tolerance Type	Slider
Tolerance Slider	0.
Tolerance Value	12.586 mm
Face/Face	Yes
Face/Edge	No
Edge/Edge	No
Priority	Include All
Same Body Grouping	Yes
Revolute Joints	Yes
Fixed Joints	Yes
Transparency	
Enabled	Yes

Mesh

TABLE 7
Model > Mesh

Object Name	*Mesh*
State	Solved
Defaults	
Physics Preference	Mechanical
Relevance	0
Advanced	
Relevance Center	Coarse
Element Size	Default
Shape Checking	Standard Mechanical
Solid Element Midside Nodes	Program Controlled
Straight Sided Elements	No

Initial Size Seed	Active Assembly
Smoothing	Low
Transition	Fast
Statistics	
Nodes	178033
Elements	90908

Zenith

TABLE 8
Model > Analysis

Object Name	*Zenith*
State	Fully Defined
Definition	
Physics Type	Structural
Analysis Type	Static Structural
Options	
Reference Temp	22. °C

TABLE 9
Model > Zenith > Analysis Settings

Object Name	*Analysis Settings*
State	Fully Defined
Step Controls	
Number Of Steps	1.
Current Step Number	1.
Step End Time	1. s
Auto Time Stepping	Program Controlled
Solver Controls	
Solver Type	Program Controlled
Weak Springs	Program Controlled
Inertia Relief	Off
Nonlinear Controls	
Force Convergence	Program Controlled
Moment Convergence	Program Controlled
Displacement Convergence	Program Controlled
Rotation Convergence	Program Controlled
Line Search	Program Controlled
Output Controls	
Calculate Stress	Yes
Calculate Strain	Yes
Calculate Results At	All Time Points
Analysis Data Management	
Solver Files Directory	H:\LICK\Lick Stuff\ansys\old truss Simulation Files\Zenith\
Future Analysis	None
Save ANSYS db	No
Delete Unneeded Files	Yes
Nonlinear Solution	No

FIGURE 1
Model > Zenith > Figure
Zenith Loading

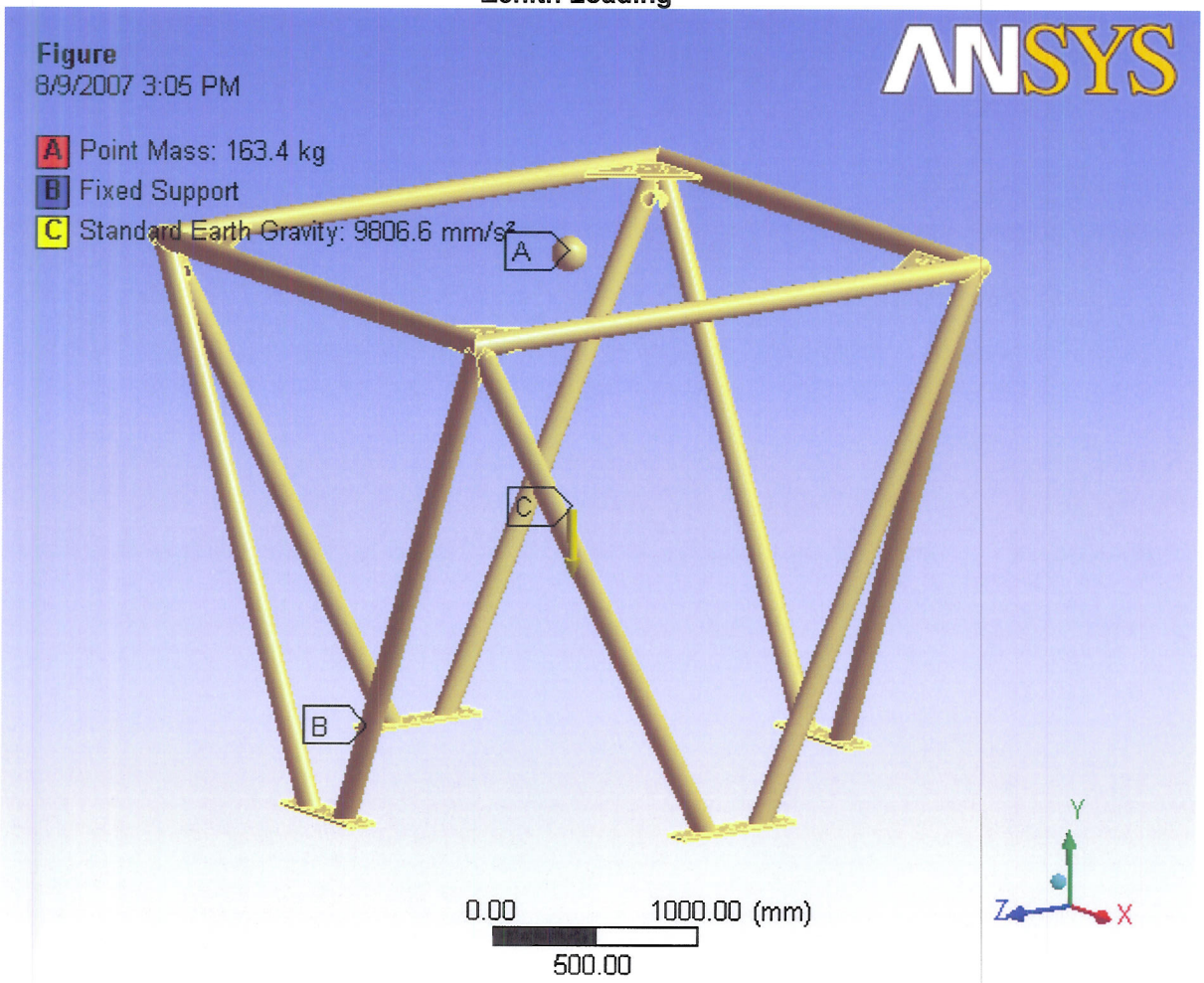


TABLE 10
Model > Zenith > Accelerations

Object Name	*Standard Earth Gravity*
State	Fully Defined
Scope	
Geometry	All Bodies
Definition	
X Component	0. mm/s² (ramped)
Y Component	-9806.6 mm/s² (ramped)
Z Component	0. mm/s² (ramped)
Suppressed	No
Direction	-Y Direction

FIGURE 2
Model > Zenith > Standard Earth Gravity

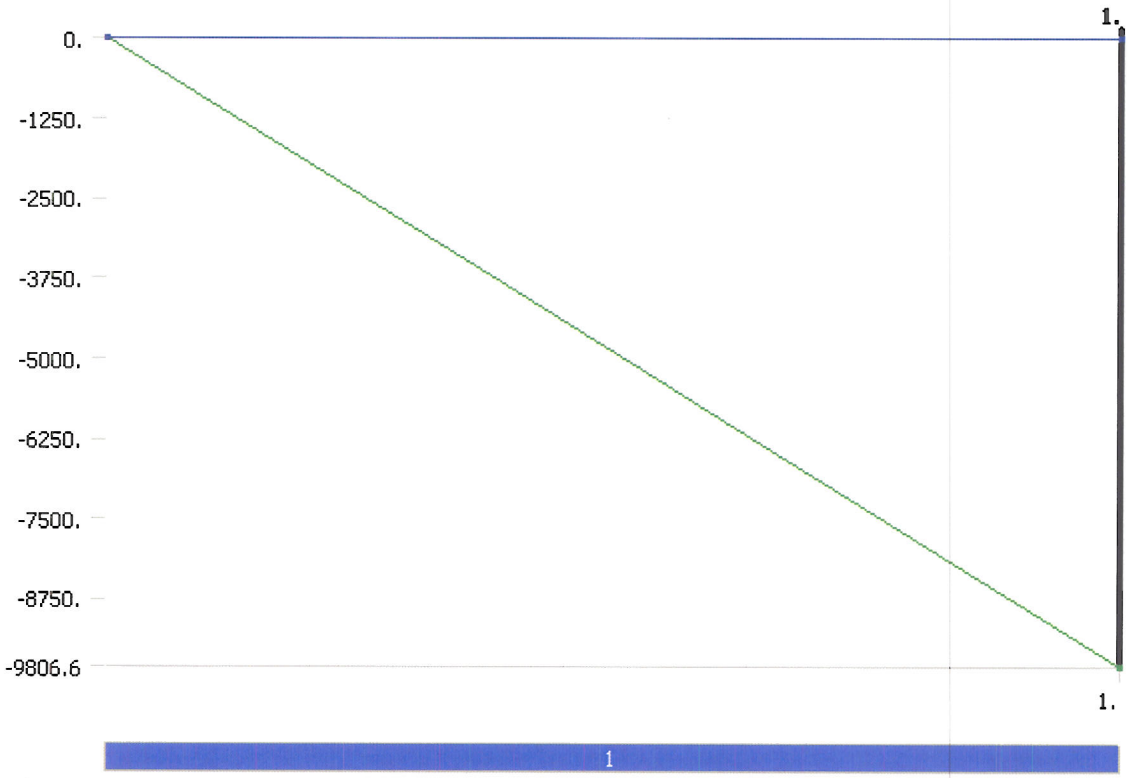


TABLE 11
Model > Zenith > Loads

Object Name	*Fixed Support*
State	Fully Defined
Scope	
Scoping Method	Geometry Selection
Geometry	4 Faces
Definition	
Type	Fixed Support
Suppressed	No

Solution

TABLE 12
Model > Zenith > Solution

Object Name	*Solution*
State	Solved
Adaptive Mesh Refinement	
Max Refinement Loops	1.
Refinement Depth	2.

TABLE 13
Model > Zenith > Solution > Solution Information

Object Name	*Solution Information*
State	Solved

Solution Information	
Solution Output	Solver Output
Newton-Raphson Residuals	0
Update Interval	2.5 s
Display Points	All

TABLE 14
Model > Zenith > Solution > Results

Object Name	*Total Deformation*	*Equivalent Stress*
State	Solved	
Scope		
Geometry	All Bodies	
Definition		
Type	Total Deformation	Equivalent (von-Mises) Stress
Display Time	End Time	
Results		
Minimum	0. mm	7.1999e-005 MPa
Maximum	0.22099 mm	17.539 MPa
Information		
Time	1. s	
Load Step	1	
Substep	1	
Iteration Number	1	

FIGURE 3
Model > Zenith > Solution > Total Deformation > Figure
Zenith Total Deformation

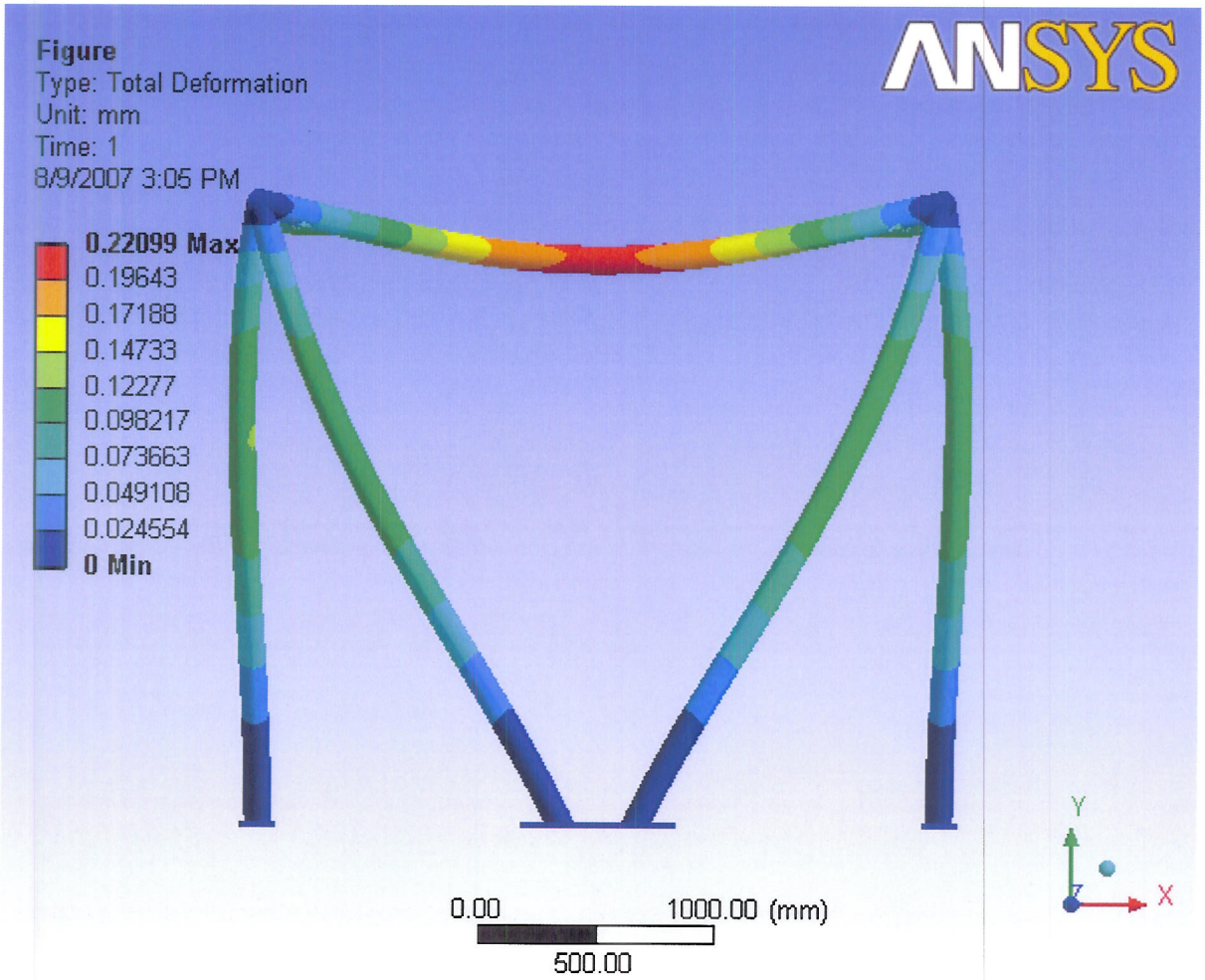


FIGURE 4
Model > Zenith > Solution > Equivalent Stress > Figure
Zenith Von Mises Stress

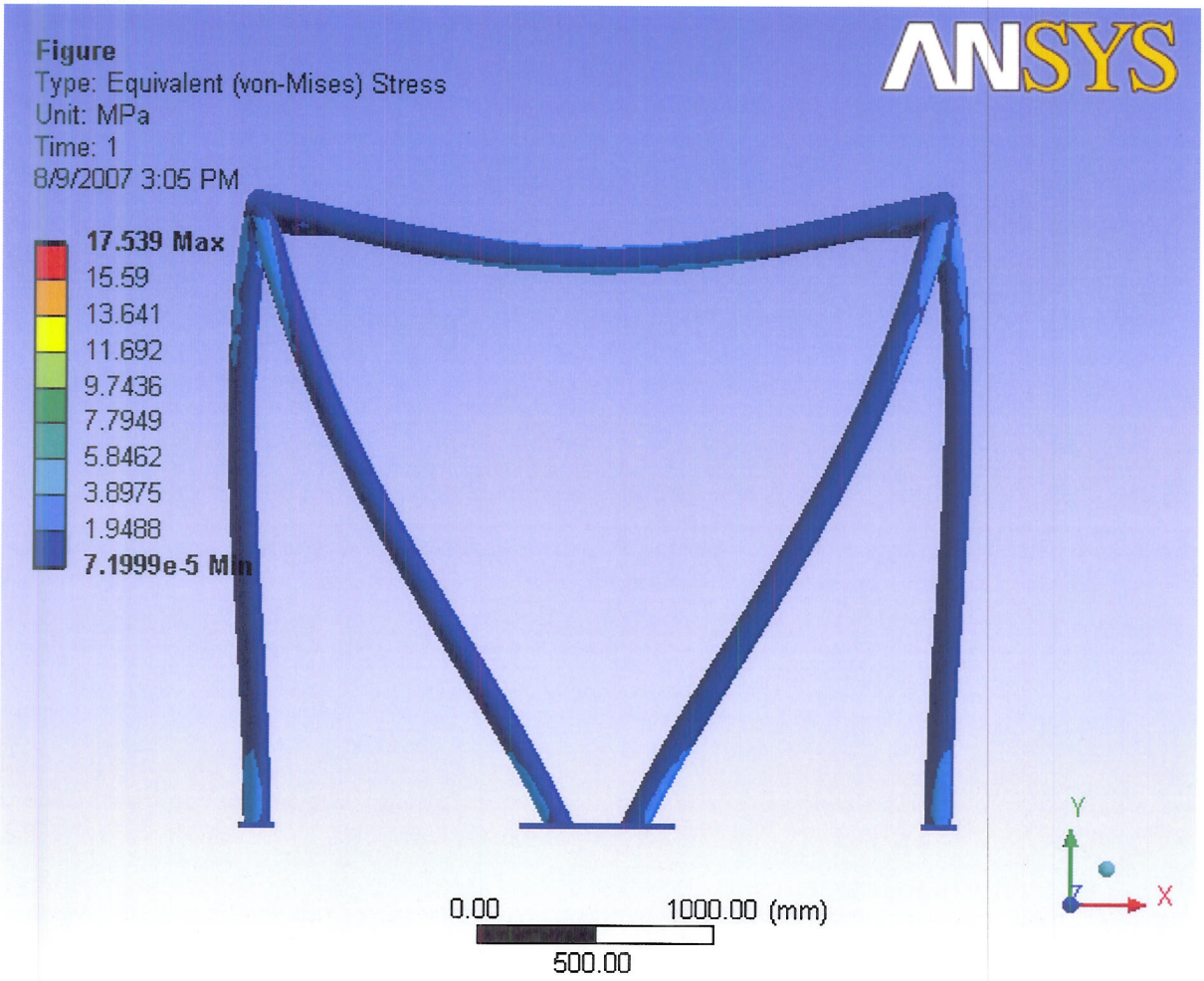


TABLE 15
Model > Zenith > Solution > Stress Safety Tools

Object Name	*Stress Tool*
State	Solved
Definition	
Theory	Max Equivalent Stress
Stress Limit Type	Tensile Yield Per Material

TABLE 16
Model > Zenith > Solution > Stress Tool > Results

Object Name	*Safety Factor*
State	Solved
Scope	
Geometry	All Bodies
Definition	
Type	Safety Factor
Display Time	End Time
Results	
Minimum	> 10

Information	
Time	1. s
Load Step	1
Substep	1
Iteration Number	1

TABLE 17
Model > Zenith > Solution > Stress Safety Tools

Object Name	*Stress Tool 2*
State	Solved
Definition	
Theory	Max Equivalent Stress
Stress Limit Type	Tensile Ultimate Per Material

TABLE 18
Model > Zenith > Solution > Stress Tool 2 > Results

Object Name	*Safety Factor*
State	Solved
Scope	
Geometry	All Bodies
Definition	
Type	Safety Factor
Display Time	End Time
Results	
Minimum	> 10
Information	
Time	1. s
Load Step	1
Substep	1
Iteration Number	1

Horizon

TABLE 19
Model > Analysis

Object Name	*Horizon*
State	Fully Defined
Definition	
Physics Type	Structural
Analysis Type	Static Structural
Options	
Reference Temp	22. °C

TABLE 20
Model > Horizon > Analysis Settings

Object Name	*Analysis Settings*
State	Fully Defined
Step Controls	

Number Of Steps	1.
Current Step Number	1.
Step End Time	1. s
Auto Time Stepping	Program Controlled
Solver Controls	
Solver Type	Program Controlled
Weak Springs	Program Controlled
Inertia Relief	Off
Nonlinear Controls	
Force Convergence	Program Controlled
Moment Convergence	Program Controlled
Displacement Convergence	Program Controlled
Rotation Convergence	Program Controlled
Line Search	Program Controlled
Output Controls	
Calculate Stress	Yes
Calculate Strain	Yes
Calculate Results At	All Time Points
Analysis Data Management	
Solver Files Directory	H:\LICK\Lick Stuff\ansys\old truss Simulation Files\Horizon\
Future Analysis	None
Save ANSYS db	No
Delete Unneeded Files	Yes
Nonlinear Solution	No

FIGURE 5
Model > Horizon > Figure
Horizon Loading

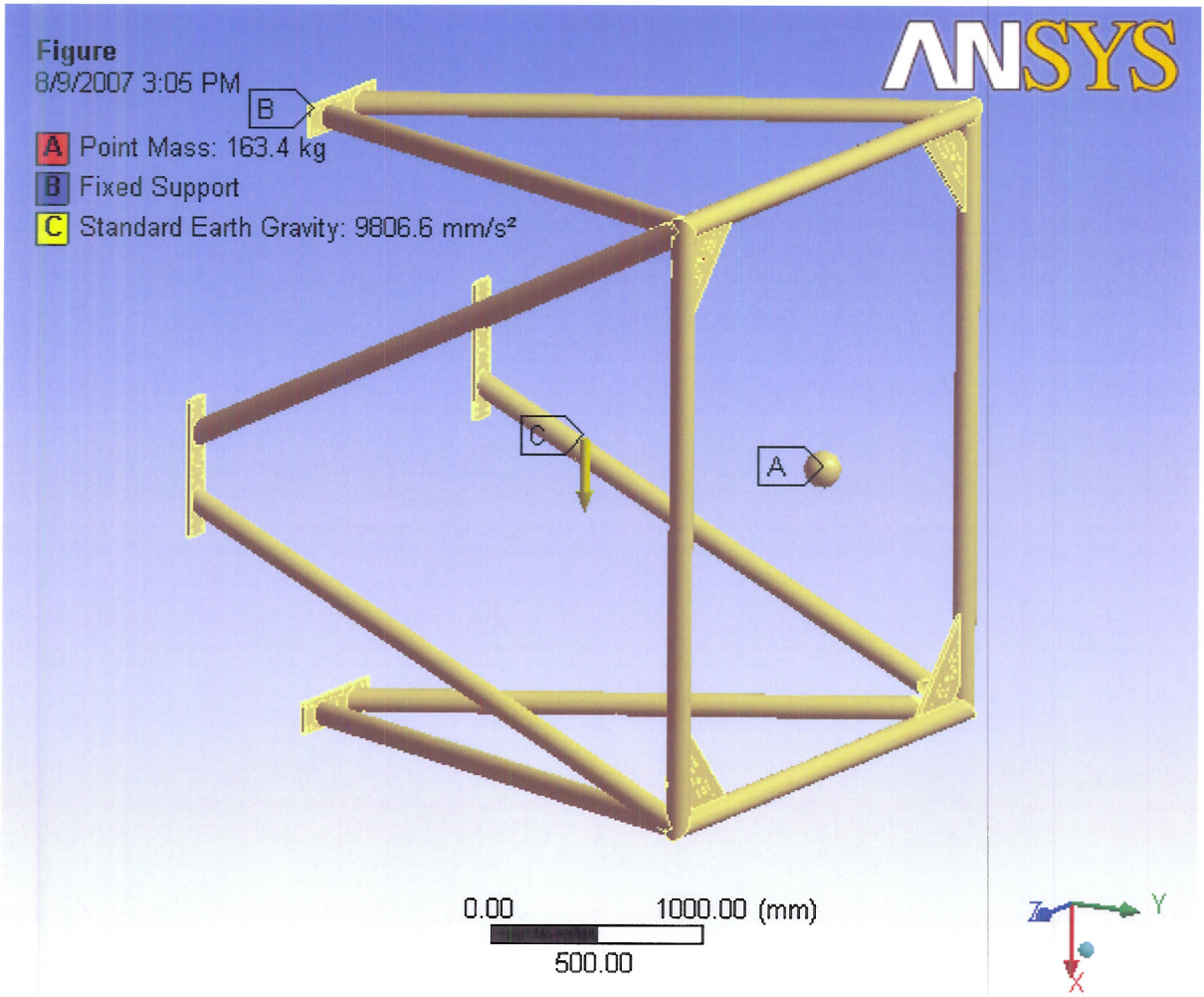


TABLE 21
Model > Horizon > Accelerations

Object Name	*Standard Earth Gravity*
State	Fully Defined
Scope	
Geometry	All Bodies
Definition	
X Component	9806.6 mm/s² (ramped)
Y Component	0. mm/s² (ramped)
Z Component	0. mm/s² (ramped)
Suppressed	No
Direction	+X Direction

FIGURE 6
Model > Horizon > Standard Earth Gravity

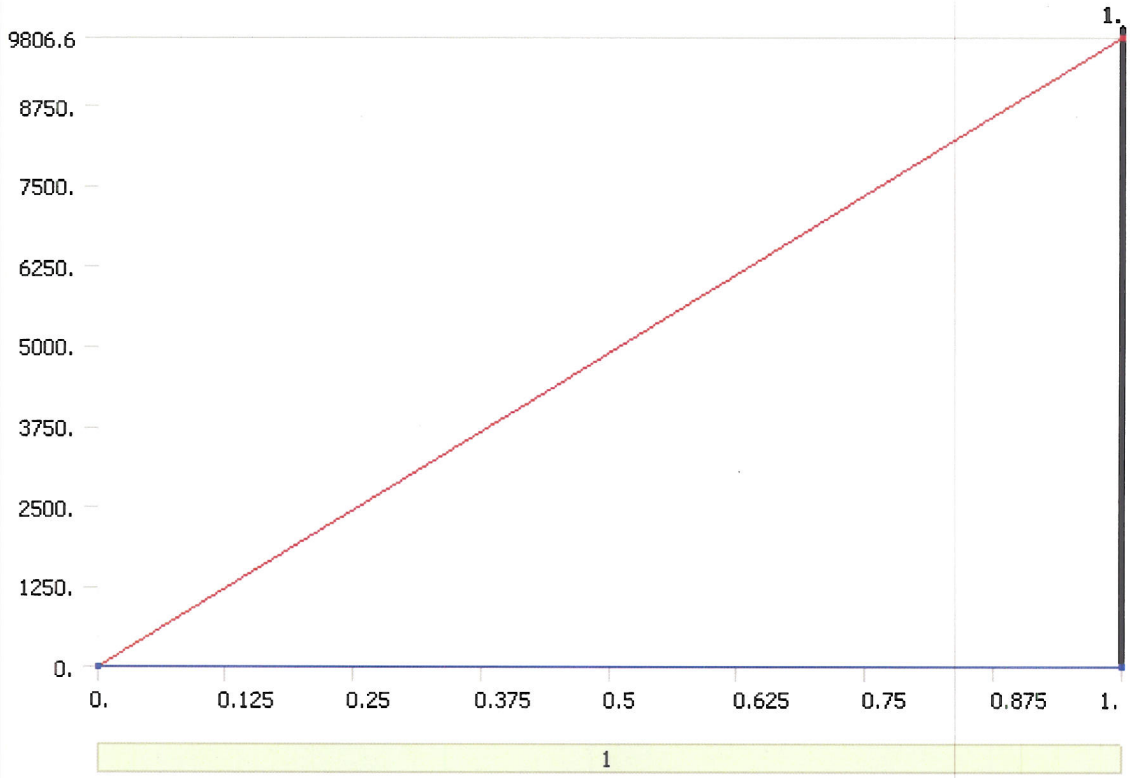


TABLE 22
Model > Horizon > Loads

Object Name	*Fixed Support*
State	Fully Defined
Scope	
Scoping Method	Geometry Selection
Geometry	4 Faces
Definition	
Type	Fixed Support
Suppressed	No

Solution

TABLE 23
Model > Horizon > Solution

Object Name	*Solution*
State	Solved
Adaptive Mesh Refinement	
Max Refinement Loops	1.
Refinement Depth	2.

TABLE 24
Model > Horizon > Solution > Solution Information

Object Name	*Solution Information*
State	Solved

Solution Information	
Solution Output	Solver Output
Newton-Raphson Residuals	0
Update Interval	2.5 s
Display Points	All

TABLE 25
Model > Horizon > Solution > Results

Object Name	*Total Deformation*	*Equivalent Stress*
State	Solved	
Scope		
Geometry	All Bodies	
Definition		
Type	Total Deformation	Equivalent (von-Mises) Stress
Display Time	End Time	
Results		
Minimum	0. mm	1.2033e-004 MPa
Maximum	0.22654 mm	16.106 MPa
Information		
Time	1. s	
Load Step	1	
Substep	1	
Iteration Number	1	

FIGURE 7
Model > Horizon > Solution > Total Deformation > Figure
Horizon Total Deformation

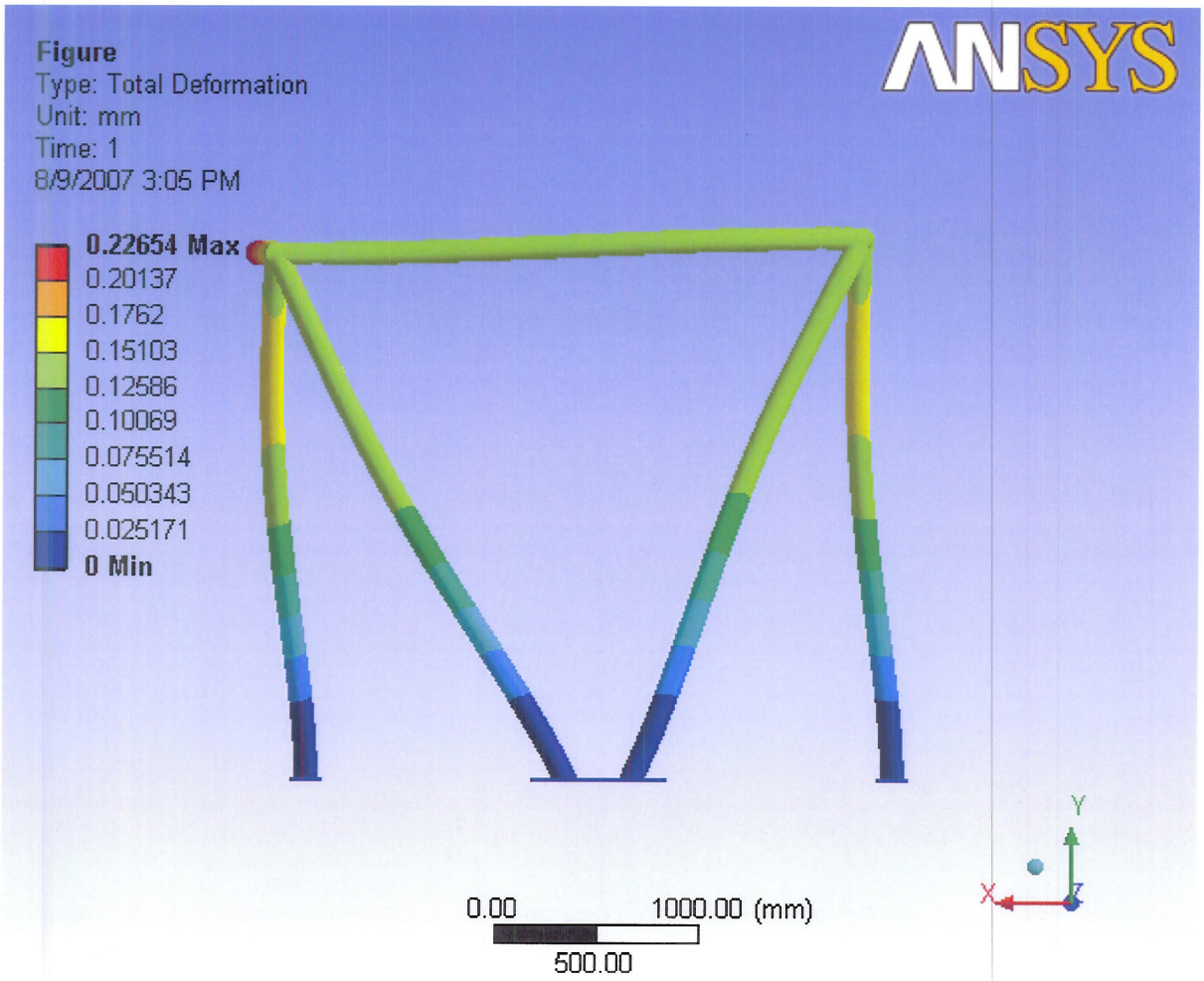


FIGURE 8
Model > Horizon > Solution > Equivalent Stress > Figure
Horizon Von Mises Stress

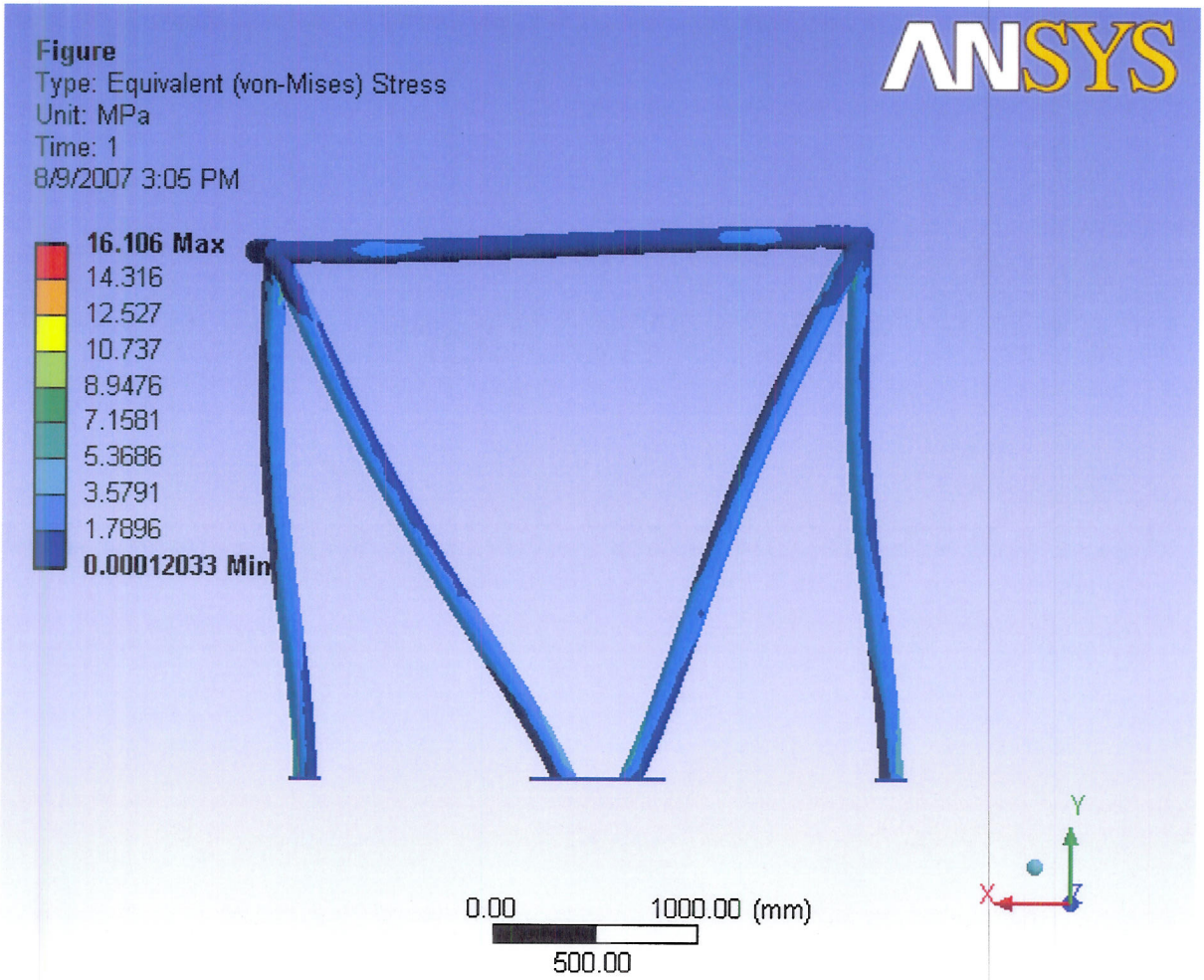


TABLE 26
Model > Horizon > Solution > Stress Safety Tools

Object Name	*Stress Tool*
State	Solved
Definition	
Theory	Max Equivalent Stress
Stress Limit Type	Tensile Yield Per Material

TABLE 27
Model > Horizon > Solution > Stress Tool > Results

Object Name	*Safety Factor*
State	Solved
Scope	
Geometry	All Bodies
Definition	
Type	Safety Factor
Display Time	End Time
Results	
Minimum	> 10

Information	
Time	1. s
Load Step	1
Substep	1
Iteration Number	1

TABLE 28
Model > Horizon > Solution > Stress Safety Tools

Object Name	*Stress Tool 2*
State	Solved
Definition	
Theory	Max Equivalent Stress
Stress Limit Type	Tensile Ultimate Per Material

TABLE 29
Model > Horizon > Solution > Stress Tool 2 > Results

Object Name	*Safety Factor*
State	Solved
Scope	
Geometry	All Bodies
Definition	
Type	Safety Factor
Display Time	End Time
Results	
Minimum	> 10
Information	
Time	1. s
Load Step	1
Substep	1
Iteration Number	1

Modal

TABLE 30
Model > Analysis

Object Name	*Modal*
State	Fully Defined
Definition	
Physics Type	Structural
Analysis Type	Modal
Options	
Reference Temp	22. °C

TABLE 31
Model > Modal > Initial Condition

Object Name	*Initial Condition*
State	Fully Defined
Definition	

Initial Condition Environment	None

TABLE 32
Model > Modal > Analysis Settings

Object Name	*Analysis Settings*
State	Fully Defined
Options	
Max Modes to Find	6
Limit Search to Range	No
Solver Controls	
Solver Type	Program Controlled
Output Controls	
Calculate Stress	No
Calculate Strain	No
Analysis Data Management	
Solver Files Directory	H:\LICK\Lick Stuff\ansys\old truss Simulation Files\Modal\
Future Analysis	None
Save ANSYS db	No
Delete Unneeded Files	Yes

TABLE 33
Model > Modal > Loads

Object Name	*Fixed Support*
State	Fully Defined
Scope	
Scoping Method	Geometry Selection
Geometry	4 Faces
Definition	
Type	Fixed Support
Suppressed	No

Solution

TABLE 34
Model > Modal > Solution

Object Name	*Solution*
State	Solved
Adaptive Mesh Refinement	
Max Refinement Loops	1.
Refinement Depth	2.

The following bar chart indicates the frequency at each calculated mode.

FIGURE 9
Model > Modal > Solution

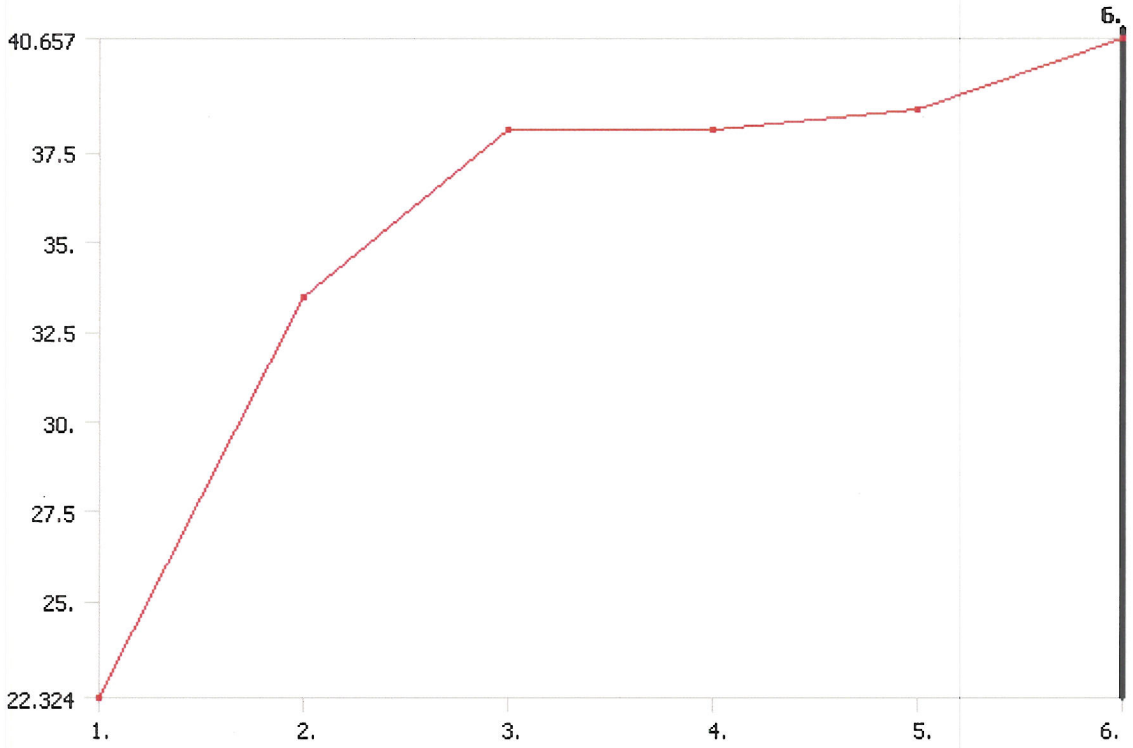


TABLE 35
Model > Modal > Solution

Mode	Frequency [Hz]
1.	22.324
2.	33.477
3.	38.12
4.	38.148
5.	38.711
6.	40.657

TABLE 36
Model > Modal > Solution > Solution Information

Object Name	*Solution Information*
State	Solved
Solution Information	
Solution Output	Solver Output
Newton-Raphson Residuals	0
Update Interval	2.5 s
Display Points	All

TABLE 37
Model > Modal > Solution > Results

Object Name	*Total Deformation*	*Total Deformation 2*
State	Solved	
Scope		

Geometry	All Bodies	
Definition		
Type	Total Deformation	
Mode	1	2
Results		
Frequency	22.324 Hz	33.477 Hz
Minimum	0. mm	
Maximum	1.2034 mm	1.7036 mm

FIGURE 10
Model > Modal > Solution > Total Deformation > Figure
1st Mode - 22Hz

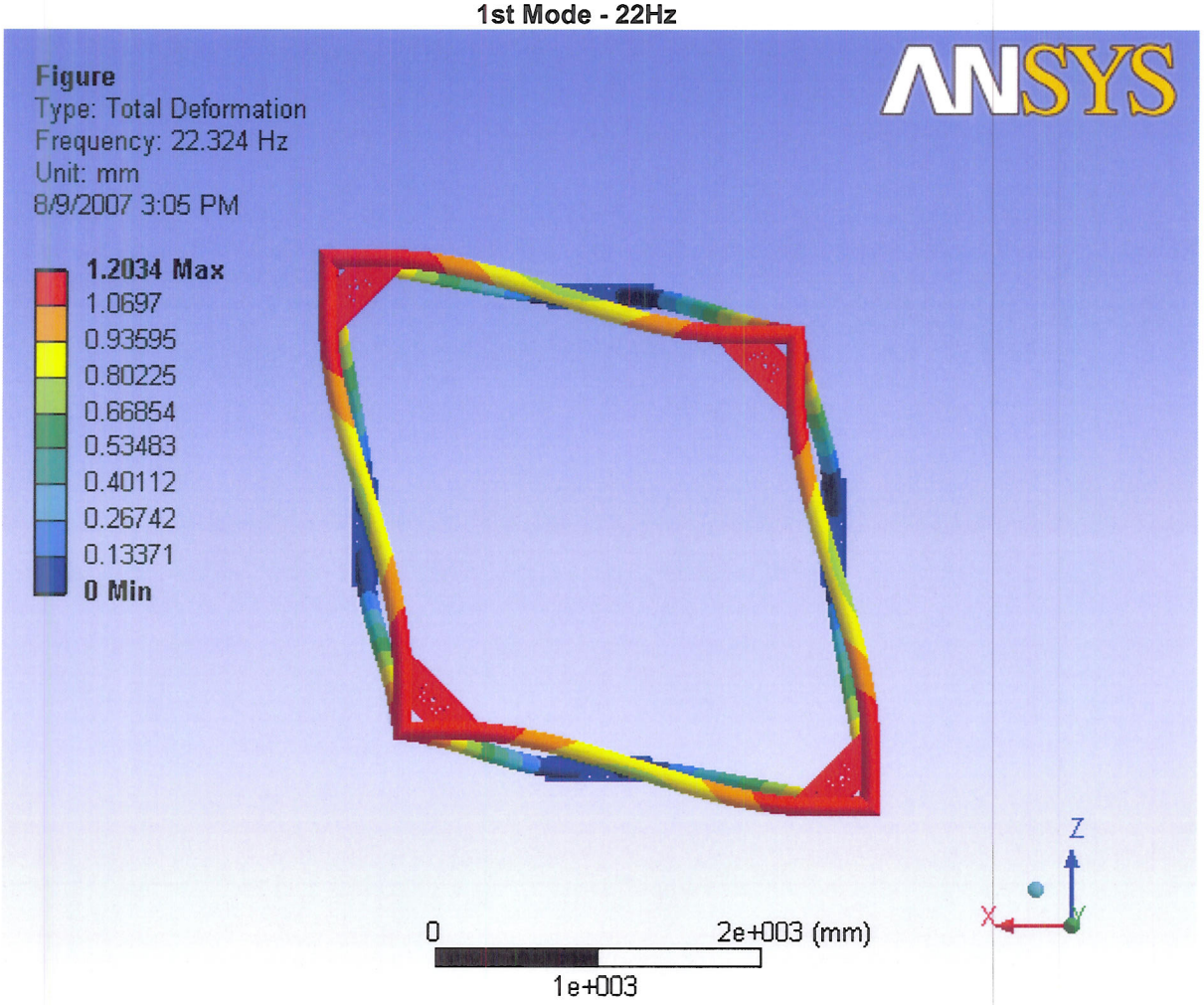
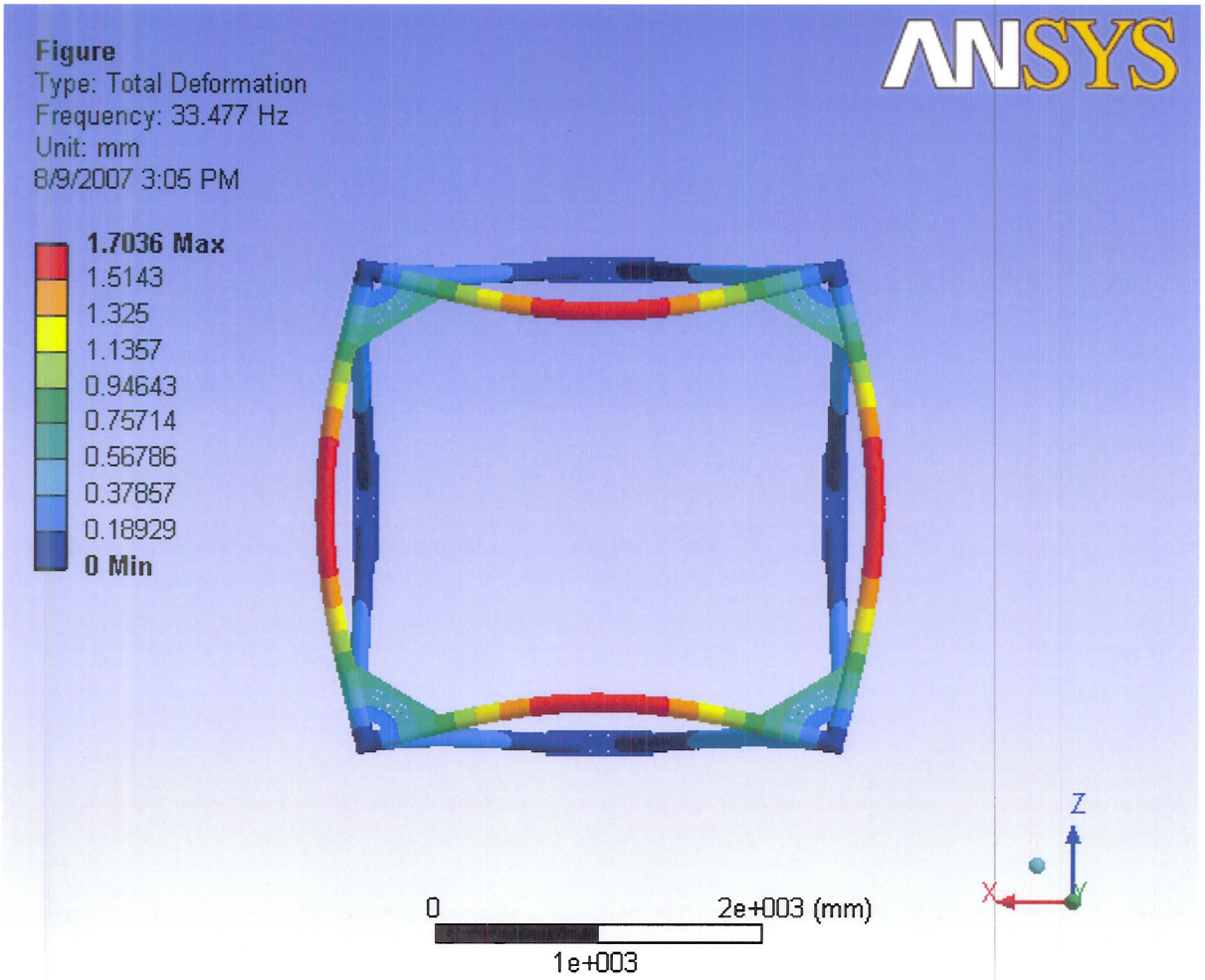


FIGURE 11
Model > Modal > Solution > Total Deformation 2 > Figure
2nd Mode - 33Hz



Material Data

Structural Steel

TABLE 38
Structural Steel > Constants

Structural	
Young's Modulus	2.e+005 MPa
Poisson's Ratio	0.3
Density	7.85e-006 kg/mm³
Thermal Expansion	1.2e-005 1/°C
Tensile Yield Strength	250. MPa
Compressive Yield Strength	250. MPa
Tensile Ultimate Strength	460. MPa
Compressive Ultimate Strength	0. MPa
Thermal	
Thermal Conductivity	6.05e-002 W/mm·°C
Specific Heat	434. J/kg·°C

Electromagnetics	
Relative Permeability	10000
Resistivity	1.7e-004 Ohm·mm

FIGURE 12
Structural Steel > Alternating Stress

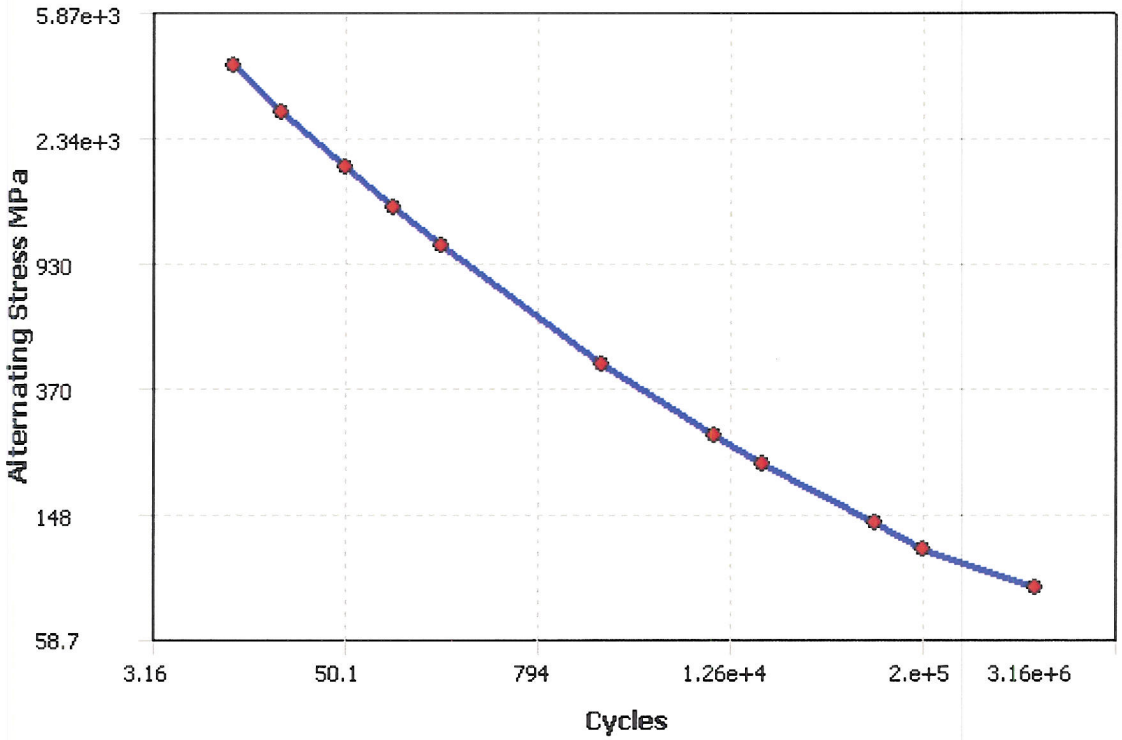


TABLE 39
Structural Steel > Alternating Stress > Property Attributes

Interpolation	Log-Log
Mean Curve Type	Mean Stress

TABLE 40
Structural Steel > Alternating Stress > Alternating Stress Curve Data

Mean Value MPa
0.

TABLE 41
Structural Steel > Alternating Stress > Alternating Stress vs. Cycles

Cycles	Alternating Stress MPa
10.	3999.
20.	2827.
50.	1896.
100.	1413.
200.	1069.
2000.	441.

10000	262.
20000	214.
1.e+005	138.
2.e+005	114.
1.e+006	86.2

FIGURE 13
Structural Steel > Strain-Life Parameters

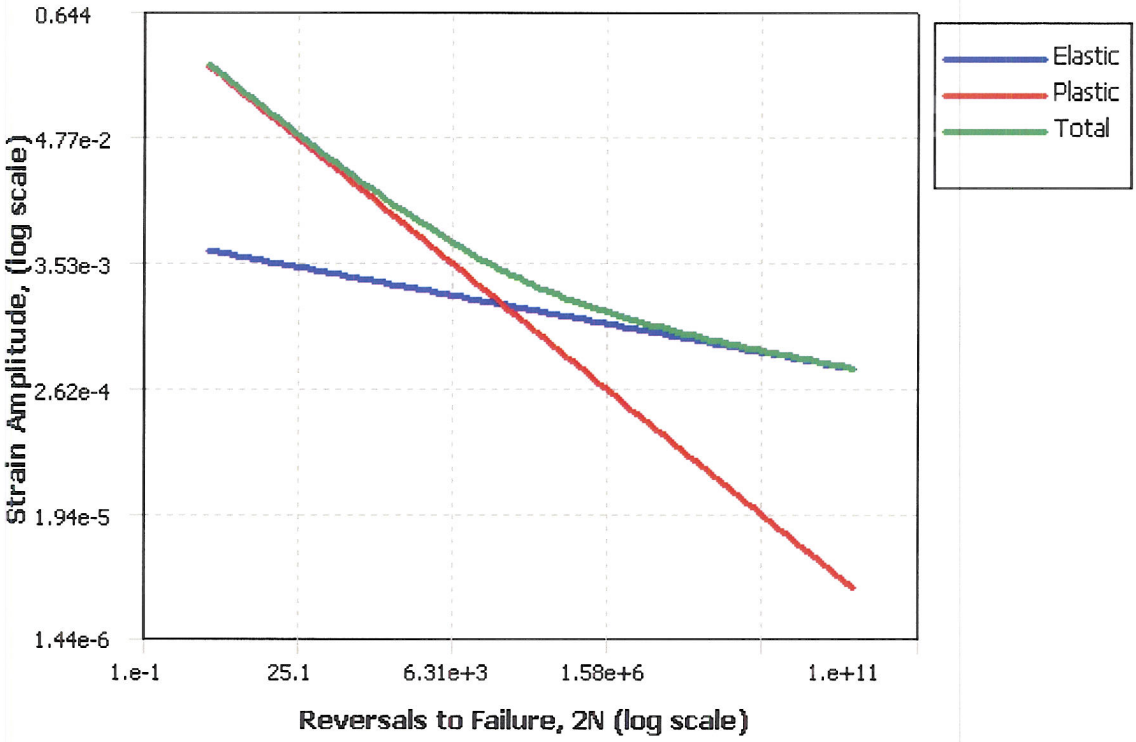


TABLE 42
Structural Steel > Strain-Life Parameters > Property Attributes

Display Curve Type	Strain-Life

TABLE 43
Structural Steel > Strain-Life Parameters > Strain-Life Parameters

Strength Coefficient MPa	920.
Strength Exponent	-0.106
Ductility Coefficient	0.213
Ductility Exponent	-0.47
Cyclic Strength Coefficient MPa	1000.
Cyclic Strain Hardening Exponent	0.2